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P.O. Drawer 10 • Bushland, Texas 79012-0010 U.S.A.
(806) 356-5724 · FAX (806) 356-5750 · 2300 Experiment Station Road

## Subsurface Drip Irrigation (SDI) Research Update at Bushland, TX

*by Paul D. Colaizzi*

Subsurface drip irrigation (SDI) is seeing increased adoption by producers in the Texas High Plains, notably in the cotton producing area around Lubbock. There is a general premise that SDI results in greater crop yields, greater water use efficiency, better cotton fiber quality, and enhanced crop earliness relative to other types of irrigation systems, and this is thought to be related to reduced evaporative cooling and the ability to maintain warmer soil temperatures during crop establishment. For some producers, these factors have justified the much greater cost, maintenance, and management requirements inherent in SDI, as well as the potential difficulties in crop germination for most High Plains soils if precipitation was inadequate prior to planting. This article reviews some recent findings on SDI research conducted at the USDA-ARS Conservation and Production Laboratory in Bushland, TX. We are presently comparing crop response, water use, and near-surface soil temperature and water content for SDI, LEPA (Low Energy Precision Applicator), and spray irrigation (i.e., MESA, or Mid-Elevation Spray Applicator, and LESA, or Low-Elevation Spray Applicator); we are also evaluating crop emergence with different bed designs and SDI lateral installation depths.

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Subsurface drip irrigation (SDI) research field at Bushland, TX showing wetting patterns of different lateral installation depths.

### Cotton and Grain Sorghum Response with MESA, LESA, LEPA, and SDI

Cotton is expanding northward into the Northern Texas High Plains and Kansas in areas where grain corn was traditionally produced. Recent shorter season varieties make cotton production more feasible in thermally-limited climates, and cotton may have similar revenue potential as corn for much less water requirement (Howell et al., 2004). Grain sorghum is commonly rotated with cotton and although it has less revenue potential, it also has less water requirement compared to corn.

Cotton and grain sorghum response were compared under MESA, LESA, LEPA, and SDI for irrigation treatments ranging from near-dryland ($I_0$) to full crop evapotranspiration ($I_{100}$), where the subscript indicates irrigation treatments relative to full crop ET. Cotton data consisted of two seasons (2003-04); the 2005 cotton crop was destroyed by hail but we plan to repeat the study in 2006. In 2003, SDI resulted in the greatest lint yield for limited irrigation treatments, but under full irrigation, MESA and LESA resulted in slightly greater lint yield than LEPA or SDI (Fig. 1a). In 2004, SDI resulted in the greatest lint yield for all irrigation treatments except $I_{25}$ (Fig. 1b). The 2004 season was relatively cool and wet, hence the reduced lint yield relative to 2003. Loan values reflected overall lint quality (length,

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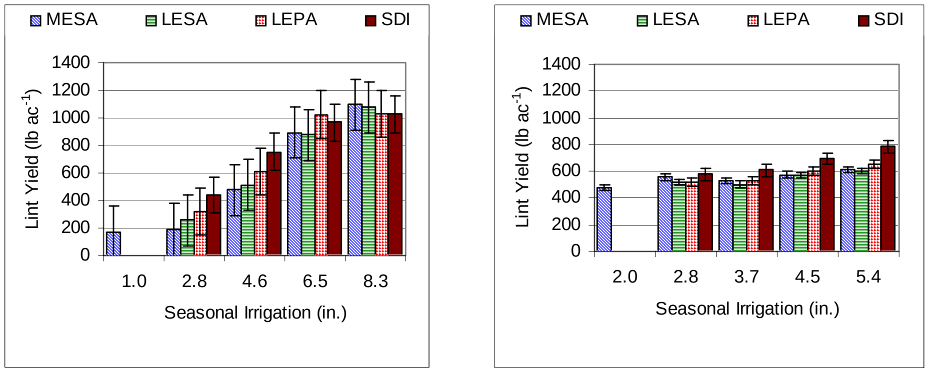
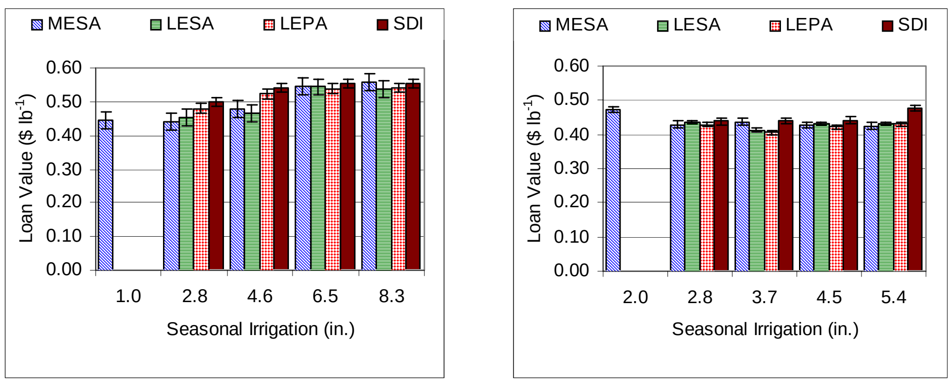
strength, uniformity, color, micronaire, etc.). Loan values followed a similar trend as lint yield in both years (Fig. 2), implying that SDI resulted in slightly better fiber quality. Seasonal water use was slightly greater for SDI at low irrigation treatments, which is likely the result of greater crop productivity; however, seasonal water use did not greatly vary between irrigation methods at greater irrigation treatments (data not shown). Additional results of the 2003-04 cotton seasons were presented by Colaizzi et al. (2005).




a) b)

Figure 1. Cotton lint yield at USDA-ARS, Bushland, TX for a) 2003; b) 2004.




a) b)

Figure 2. Cotton loan values at USDA-ARS, Bushland, TX for a) 2003; b) 2004.

Grain sorghum yield averaged over three seasons (2000-02) resulted in a trend similar to cotton, in that SDI resulted in largest yields under lower irrigation treatments ($I_{25}$ and $I_{50}$), but MESA and LESA resulted in the greatest yields at high irrigation treatments ($I_{75}$ and $I_{100}$) (Fig. 3). At low irrigation treatments, seasonal water use did not vary greatly among irrigation methods; however, at higher irrigation treatments, SDI and LEPA sometimes resulted in less water use, probably due to reduced crop productivity (data not shown; see Colaizzi et al., 2004 for additional details). It appears that SDI, and to a lesser extant LEPA, results in greater partitioning of water to plant transpiration relative to spray at low irrigation treatments, which results in greater crop yield. At greater irrigation treatments, the yield depression of SDI and LEPA relative to spray is not clear, although it may be the result of poor aeration and nutrient leaching. Colaizzi et al. (2006a) reviewed crop response under various irrigation systems at other locations (Halfway, TX and Colby, KS), and crop yield trends were often similar among SDI, LEPA, and spray. These results demonstrate that with proper design, maintenance, and management, SDI can result in greater crop yield relative to other irrigation systems under limited irrigation. With escalating energy costs, many producers will be forced to reduce irrigation pumping and utilize deficit irrigation management.

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*Editors:* Dr. Terry A. Howell, P.E./Nancy Davis
USDA-ARS
P.O. Drawer 10
Bushland, TX 79012-0010

email: tahowell@cprl.ars.usda.gov / ndavis@cprl.ars.usda.gov
Phone: (806)356-5746 / (806)356-5732
Fax: (806)356-5750
Shipping: 2300 Experiment Station Road

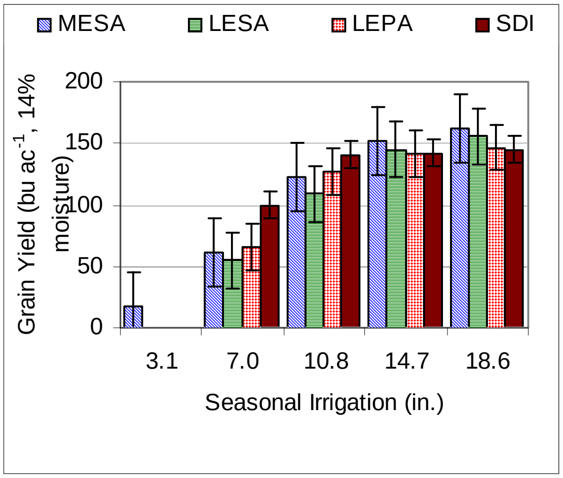


Figure 3. Grain sorghum yield at USDA-ARS, Bushland, TX, averaged for 2000, 2001, and 2002 seasons.

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## Soil Temperature with MESA, LESA, LEPA, and SDI

Detained studies of near-surface soil temperature and volumetric water content under different irrigation systems were initiated in the 2005 season at Bushland. Arrays of thermocouples and TDR probes (Evett et al., 2005) were installed in raised beds at 2-, 4-, and 6-in. depths for MESA, LESA, LEPA, and SDI treatments. Accumulated soil heat units were computed as the measured soil temperature above a baseline temperature (60°F in this case, as commonly used for cotton) after planting soybeans on June 20, 2005, which replaced cotton destroyed by hail. For all three measurement depths, SDI resulted in greater soil heat unit accumulation than LEPA, which in turn was greater than MESA and LESA at 35 days (Fig. 4a) and 50 days (Fig. 4b) after planting. These preliminary results support the hypothesis that SDI results in warmer soil temperatures during early crop development; however, this experiment is being continued for additional crop seasons (see Colaizzi et al., 2006b for additional details).

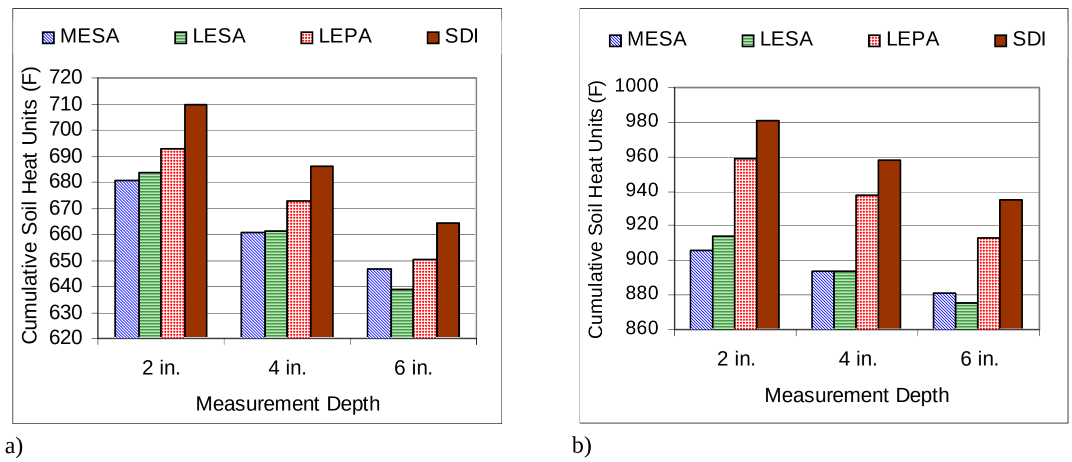


Figure 4. Soybean cumulative soil heat units (above 60°F baseline) in 2005, a) 35 days after planting; b) 50 days after planting.

## Crop Emergence with Alternative SDI Designs

Drip laterals comprise two-thirds or more of the SDI system installation costs. For low value row crops (which represent most of the irrigated land area in the High Plains), drip laterals are commonly installed in alternate furrows (Fig. 5a), and higher value crops are usually required to justify the additional cost and maintenance requirements of installing laterals in every row. The alternate-furrow installation requires the wetting front to travel much further from the lateral to the seed bed. This poses considerable risk for crop establishment if the near-surface soil profile is dry and if soil conditions are unfavorable for the horizontal or upward movement of water, such as in the presence of cracks (Howell et al., 1997), soil compaction (Enciso et al., 2005), or relatively low capillary potential. Dry soil conditions at planting have been increasingly common in recent years due to widespread drought, and excessive irrigation water is sometimes required to germinate the crop, defeating the purpose of SDI.

The wide bed, or twin row design is being evaluated as a potential alternative to conventional beds with laterals in alternate furrows (Fig. 5b). This design has been used successfully in the Southeastern U.S. for corn (Phene, 1974; Phene and Beale, 1979), in Israel for cotton (Oron, 1984), and by producers in Arizona for numerous crops. Seedling emergence was compared for wide beds and conventional beds (laterals installed in alternate furrows) at irrigation treatments ranging from dryland to full crop evapotranspiration. Lateral installation depths were varied at 6-, 9-, and 12-in. as a subplot factor. Soybeans were planted in 2004 and corn in 2005; however, above average rainfall masked any differences in crop emergence. The corn was destroyed by hail in 2005, and the near-surface soil profile had dried considerably upon replanting the field in soybeans. Therefore, soybean emergence could be related to experimental treatments.

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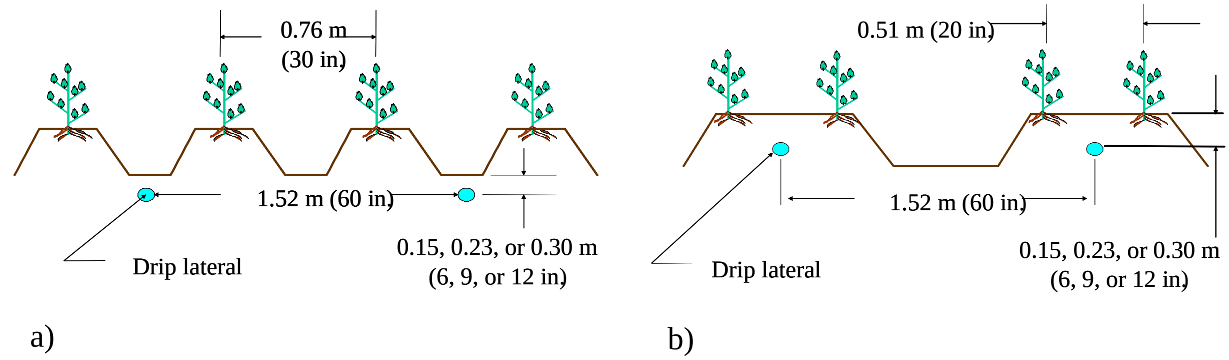


Figure 5. SDI bed designs and lateral installation depths, a) laterals in alternate furrows; b) wide bed, twin row.

The wide bed design resulted in greater crop emergence than the standard bed design by 13 days after planting, and the 9-in. lateral installation depth resulted in slightly greater emergence compared to the 6- or 12-in. depths (Fig 6a). For the standard bed design, emergence decreased with deeper lateral depths. After 29 days from planting, wide bed emergence remained greater than emergence for standard beds for the $I_{33}$ and $I_{67}$ irrigation treatments; however, average emergence was similar for each design at the $I_{100}$ treatment (Fig. 6b). In the wide beds, emergence using the 9-in. lateral depth remained greater than the 6- or 12-in. depths. This depth may be a trade-off between adequate soil water required for crop germination without excessive cooling of the seed bed, although we did not measure soil temperature as was done in the other experiment. The 9-in. depth was also the minimum that would allow sufficiently deep tillage to remove crop residue, soil crust, and weeds in a single pass. This experiment will be continued for the 2006 and future seasons, and further details are provided by Colaizzi et al. (2006c).

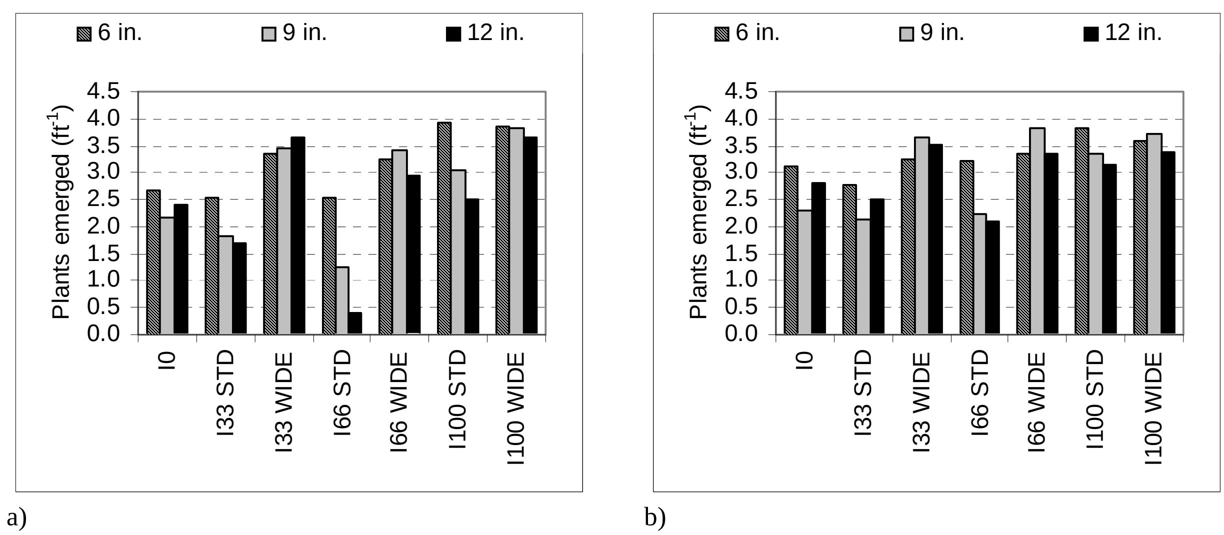


Figure 6. Soybean emergence in 2005, a) 13 days after planting; b) 29 days after planting (V4 to V5 stage).

## Potential for SDI Expansion in the Texas High Plains

The Texas Water Development Board (TWDB) has conducted irrigation surveys in cooperation with the Natural Resource Conservation Service (NRCS) and the Texas State Soil and Water Conservation Board about every five years since 1958; the most recent was in 2000 (TWDB, 2001). From the 2000 survey, the 39 counties in the Texas Agricultural Statistics Service (TASS) Northern and Southern High Plains Districts contained a total of 4.6 million irrigated acres (Table 1). Irrigation technology consisted of about 72% sprinkler (nearly all mechanically-move center pivots), 27% percent gravity (mostly graded furrow), and less than 0.5% drip (mostly SDI). The proportion of sprinkler irrigation has increased significantly from 44% in 1989 (Musick et al., 1990). Most of the drip area was in the Southern High Plains (20,600 ac) where cotton is primarily produced, although some industry suppliers believe the SDI

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area has increased to 60,000 acres by 2006. The potential for SDI expansion appears large given its small portion of total irrigated area, especially considering the amount of land still irrigated by gravity (nearly 1.3 million acres as of 2000). As cotton expands northward into the Northern High Plains District, SDI may play a more critical role in mitigating cool soil temperatures early in the season, which limit crop establishment.

Table 1. Texas High Plains irrigation inventory, 2000 (TWDB, 2001).

| TASS District | Drip (ac) | Sprinkler (ac) | Gravity (ac) | Total (ac) | Irrig. Use (ac-ft) | Avg. Depth (in.) |
|---|---|---|---|---|---|---|
| 11 (NHP) | 1,300 | 1,855,700 | 937,400 | 2,794,300 | 4,164,200 | 17.9 |
| | 0.05% | 66.4% | 33.5% | | | |
| 12 (SHP) | 20,600 | 1,487,600 | 324,000 | 1,832,100 | 2,340,500 | 15.3 |
| | 1.12% | 81.2% | 17.7% | | | |
| Total | 21,900 | 3,343,200 | 1,261,300 | 4,626,400 | 6,504,700 | 16.9 |
| | 0.47% | 72.3% | 27.3% | | | |

## Conclusions

Several studies are underway at the USDA-ARS at Bushland, TX to investigate relative crop response, water use, and near-surface soil temperature and moisture contents for SDI, LEPA, and spray irrigation methods, as well as crop establishment and productivity under alternative bed designs and lateral depth installations. Data so far indicate that although seasonal water use did not vary greatly among different irrigation methods for a given irrigation treatment, crop productivity tended to be greater with SDI compared with LEPA or spray at low irrigation treatments (i.e., 50% or less of full crop ET), whereas LEPA and/or spray irrigation resulted in productivity equal to or greater than SDI at greater irrigation treatments. Preliminary data also indicate that SDI results in greater soil temperature early in the season compared with LEPA or spray irrigation, which may be linked to better cotton fiber quality that was sometimes observed. The wide bed design containing a drip lateral centered between two rows resulted in greater crop emergence compared to conventional beds with laterals installed in alternate furrows, which may overcome difficulties in crop establishment following off-season drought.

## References


Colaizzi, P. D., A. D. Schneider, S. R. Evett, and T. A. Howell. 2004. Comparison of SDI, LEPA, and spray irrigation performance for grain sorghum. *Trans. ASAE.* 47(5): 1477-1492.

Colaizzi, P.D., S. R. Evett, and T. A. Howell. 2005. Cotton production with SDI, LEPA, and spray irrigation in a thermally-limited climate. CD-ROM. Irrigation Association Annual Meeting, 6-8 Nov, Phoenix, AZ.

Colaizzi, P. D., F. R Lamm, T. A. Howell, and S. R. Evett. 2006a. Crop production comparison under various irrigation systems. In *Proc. Central Plains Irrigation Conference*, Colby, KS., Feb. 21-22, 2006. Available from CPIA, 760 N. Thompson, Colby, KS. pp. 189-207 (Invited).

Colaizzi, P.D., S. R. Evett, and T. A. Howell. 2006b. Crop emergence and near-surface soil water and temperature for SDI, LEPA, and spray irrigation. Paper Number: 062278. 2006 ASABE Annual International Meeting, Sponsored by American Society of Agricultural and Biological Engineers, 9-12 July, Portland, OR.

Colaizzi, P.D., S. R. Evett, and T. A. Howell. 2006c. SDI wide bed design improves row crop emergence. Paper Number: 062279. 2006 ASABE Annual International Meeting, Sponsored by American Society of Agricultural and Biological Engineers, 9-12 July, Portland, OR.

Enciso, J. M., P. D. Colaizzi, and W. L. Multer. 2005. Economic analysis of subsurface drip irrigation lateral spacing and installation depth for cotton. *Trans ASAE.* 48(1): 197-204.

Evett, S.R., J.A. Tolk, and T.A. Howell. 2005. TDR laboratory calibration in travel time, bulk electrical conductivity, and effective frequency. *Vadose Zone Journal* 4:1020-1029, Special Section: Soil Water Sensing. doi:10.2136/vzj2005.0046

Howell, T. A., A. D. Schneider, and S. R. Evett. 1997. Subsurface and surface microirrigation of corn—Southern High Plains. *Trans. ASAE* 40(3): 635-641.

Howell, T. A., S. R. Evett, J. A. Tolk, and A. D. Schneider. 2004. Evapotranspiration of full-, deficit-irrigation, and dryland cotton on the Northern Texas High Plains. *J. Irrig. Drain. Engrg*., Am. Soc. Civil Engrgs. 130(4): 277-285.

Musick, J. T., F. B. Pringle, W. L. Harman, and B. A. Stewart. 1990. Long-term irrigation trends - Texas High Plains. *Appl. Eng. Agric*. 6(6): 717-724.

Oron, G. 1984. Yield of single versus twin-row trickle irrigated cotton. *Agric. Water Manage*. 9(3):237-244.

Phene, C. J. 1974. Subsurface irrigation in the humid Southeastern Coastal Plains. In *Proc. Symposium On Water Resources: Utilization and Conservation in the Southeastern Environment*, Ft. Valley, Ga., M. C. Blount, ed. 267-303.

Phene, C. J. and O. W. Beale. 1979. Influence of twin-row spacing and nitrogen rates on high-frequency trickle-irrigated sweet corn. *Soil Sci. Soc. Am. J.* 43(6):1216-1221.

TWDB, 2001. Surveys of irrigation in Texas, 1958, 1964, 1969, 1974, 1979, 1984, 1989, 1994, and 2000. Texas Water Development Board, Rep. 347. Available at: http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R347/R347.pdf (accessed 20 April 2006).

## New Publications

Allen, R.G., W.O. Pruitt, J.L. Wright, **T.A. Howell**, F. Ventura, R. Snyder, D. Itenfisu, P. Steduto, J. Berengena, J.B. Yrisarry, M. Smith, L.S. Pereira, D. Raes, A. Perrier, I. Alves, I. Walter, R. Elliott. 2006. A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method. Agricultural Water Management 81:1–22.

**Baumhardt, R.L.,** and **T.A. Howell**. 2006. Seeding practices, cultivar maturity, and irrigation effects on simulated grain sorghum yield. Agron. J. 98(2):462-470.

**Baumhardt, R.L., J.A. Tolk, T.A. Howell**, and W.D. Rosenthal. 2006. Modeling to evaluate irrigation and crop management strategies for maximizing grain sorghum yield and water use efficiency. Biological Systems Simulation Group, 11-13 April 2006, Fort Collins, Colorado. (Proceedings)

**Colaizzi, P.D.**, F. R Lamm, **T.A. Howell**, and **S. R. Evett**. 2006. Crop production comparison under various irrigation systems. In: Proc. Central Plains Irrigation Conference, Colby, KS., Feb. 21-22. pp. 189-207.

**Colaizzi, P.D., S.R. Evett, T.A. Howell, J. A. Tolk**, and F. Li. 2006. Evaluation of a two-source energy balance model in an advective environment. In Proc. ASCE-EWRI World Water and Environmental Resources Congress 2005, 21-25 May, Omaha, NE.

Cole, N.A., **R.C. Schwartz**, and R.W. Todd. 2005. Assimilation versus accumulation of macro- and micronutrients in soils: Relations to livestock and poultry feeding operations. J. Appl. Poul. Res. 14:393-405.

Dao, T.H., E.E., Codling, **R.C. Schwartz,** 2005. Time Dependent Phosphorus Extractability in Calcium and Iron-Treated High-Phosphorus Soils. Soil Science. 170:810-821.

Esparza, A.M., **P.H. Gowda**, **R.L. Baumhardt**, and C. A. Robinson. 2006. Climatic risk to cotton production in the southern high plains region. World Environmental & Water Resources Congress sponsored by Environmental & Water Resources Institute, American Society of Civil Engineers, May 21-25, Omaha, NE, 10p

Esparza, A.M., **P.H. Gowda**, **R.L. Baumhardt**, and C.A. Robinson. 2006. Thermal viability of cotton production in the Ogallala Aquifer Region. Proceedings of the West Texas A&M University 12th Annual Student Research Conference, March 3, 2006, 12p.

**Evett, S.R., J.A. Tolk, and T.A. Howell**. 2006. Soil Profile Water Content Determination: Sensor Accuracy, Axial Response, Calibration, Temperature Dependence and Precision. Accepted for publication by Vadose Zone Journal

**Gowda, P.D.,** R.T. Peters, and **T.A. Howell**. 2006. Mapping Contrasting tillage practices in the Texas panhandle with landsat thematic mapper (TM) data. In: Proc. ASCE-EWRI World Water and Environmental Resources Congress, 21-25 May 2006, Omaha, Nebraska. (Proceedings)

**Howell, T.A**. 2006. Water Losses Associated with Center Pivot Nozzle Packages. In Proc. 2006 Central Plains Irrigation Conference, Colby, Kansas, Feb 21-22. pp. 11-24.

**Howell, T. A., S.R. Evett, J.A. Tolk, K.S. Copeland, D.A. Dusek, and P.D. Colaizzi**, Crop coefficients developed at Bushland, Texas for corn, wheat, sorghum, soybean, cotton, and alfalfa. In: Proc. ASCE-EWRI World Water and Environmental Resources Congress, 21-25 May 2006, Omaha, Nebraska. (Proceedings)

**Howell, T.A.**, and M. Meron, 2006. Irrigation scheduling, Chapter 3. In: J. E.Ayars, F. R. Lamm, and F. Nakayama (eds.) Microirrigation for Crop Production, Second Edition, Elsevier Publishers. 2006. (in press) (Book Chapter)

**Howell, T.A.** 2006. Challenges in increasing water use efficiency in irrigated agriculture. In: proceedings International Symposium on Water and Land Management for Sustainable Irrigated Agriculture, Adana-TURKEY, 4 – 8 April, 2006, Cukurova Univ. (Proceedings)

Irmak, S., **T.A. Howell**, R.B. Allen, J.O. Payero, and D.L. Martin. 2005. Standardized ASCE Penman-Monteith: impact of sum-of-hourly vs. 24-hour timestep computations at reference weather station sites. Trans. ASAE 48(3):1063-1077.

Lamm, F.R., **T.A. Howell**, and J.P. Bordovsky. 2006. Concepts of in-canopy and near-canopy sprinkler irrigation. In: Proc. ASCE-EWRI World Water and Environmental Resources Congress, 21-25 May 2006, Omaha, Nebraska. (Proceedings)

Peters, R.T., and **S.R. Evett**. 2006. Center-Pivot Automation: Using crop canopy temperature to eliminate irrigation guesswork. In Resource: Engineering and Technology for a Sustainable World. Vol. 13 No.2 March 2006. pp. 9-10.

**Peters, R.T**., and **S.R. Evett**. 2006. An artificial dry Reference surface for predicting canopy temperature dynamics from a moving irrigation system. In: Proc. ASCE-EWRI World Water and Environmental Resources Congress, 21-25 May 2006, Omaha, Nebraska. (Proceedings)

Pikul Jr, J.L., **R.C. Schwartz,** J.G. Benjamin, **R.L. Baumhardt,** S.D. Merrill. 2006. Cropping Systems Influences on Soil Physical Properties in the Great Plains. Renewable Agriculture and Food Systems. 21:15-25.

**Schwartz, R.C**., **J.M. Bell.** 2006. Changes in Extractable Phosphorus in Amended Soils During a Growing Season. In: Proceedings Great Plains Soil Fertility Conference, March 7-8, 2006, Denver, Colorado. P. 257-263.

**Tolk, J.A., T.A. Howell, and S.R. Evett**. 2006. Nighttime evapotranspiration from alfalfa and cotton in a semiarid environment. To appear in the May-June issue of Agronomy Journal.

Varvel, G.E., Riedell, W.E., Deibert, E., Mcconkey, B., Tanaka, D.L., Vigil, M.F., **Schwartz, R.C.** 2006. Great Plains Cropping System Studies for Soil Quality Assessment. Renewable Agriculture and Food Systems. 21:3-14.

# Non-Uniform Planting Geometry for Dryland Grain Sorghum; Thoughts from Outside of the Box on Clump Planting

*by R. Louis Baumhardt*

Although it is fast becoming cliché to "*Think Outside of the Box*," a common hazard for thoughts of this origin is that they are quickly supplied a box either for storage or, most often, burial. Dr. Bob Stewart, Director Dryland Institute – WTAMU, approached me with an *out-of-box* experiment on clump planting grain sorghum [*Sorghum bicolor* (L.) Moench] to reduce vegetative growth and increase yield. The break from uniformly planting crops to optimize distribution over an area for efficient use of water and irradiant energy sent me looking for a suitably sturdy box. Nevertheless, his impassioned thesis why clump planting was superior for dryland sorghum convinced me to helpout on this new study that we agreed to keep, initially, in more remote places of the Conservation & Production Research Laboratory at Bushland, TX. This *Wetting Front* report summarizes a portion of the results from that test, which will be documented in the Agronomy Journal by Bandaru et al. (In Press).

Grain sorghum is a feed crop grown on the Southern Great Plains under both dryland and irrigated conditions either as a primary or a catch crop. Unger and Baumhardt (1999) noted that the introduction of improved hybrids and water conserving residue management practices have increased dryland grain sorghum yields at the USDA-ARS Conservation and Production Research Laboratory, Bushland, TX 139% between 1956 and 1997. However, dryland grain sorghum yields on the U.S. southern Great Plains are generally low and highly variable because of limited and erratic growing season precipitation. Water deficit stress during boot and flowering stages, i.e. reproduction and grain fill, depresses sorghum grain yield by as much as 85% (Craufurd et al., 1993). Reduced populations and skip row planting strategies have been used to extend soil water availability later into the growing season to increase yield (Baumhardt et al., 2005; Larson and Vanderlip, 1994). But, uniformly planted narrow row sorghum maximizes light interception by the crop (Steiner, 1986).

Under dryland conditions, planting sorghum in clumps (left) decreases tillering, biomass production, and defers water use for grain yield compared with sorghum planted in uniform rows that when severely water stressed fails to make grain

On the southern High Plains, grain sorghum is planted during early summer when precipitation and soil water conditions are suitable for rapid vegetative growth that encourages tillering. In grain sorghum, normal tiller growth will produce leaf and stem structures similar to the mainstem terminating with a fertile panicle. If water becomes limiting, complete tiller leaf and subsequent panicle development ceases; however, water and nutrients consumed for tiller growth are of little or no value. It was hypothesized that growing sorghum in clumps would increase competition among plants for water and nutrients, reduce tillering, and decrease overall soil water use for vegetative growth. The study objective was to compare the growth and yield of sorghum planted in clumps with uniformly spaced plants at the same population and field conditions.

**Experimental**

I summarize a portion of V. Bandaru's full planting geometry study (guided by B.A. Stewart) that was conducted in 2003 and 2004 at Bushland, TX (35°11'N, 102°5'W) on a Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll) with 0 - 2 % slope and a plant available water storage capacity of ~ 230 mm to a depth of 1.8 m (Unger, 1978). All fields had been fallowed ~ 11 months after wheat (*Triticum aestivium* L.) harvest in the wheat-sorghum-fallow cropping sequence (Jones and Popham, 1997). The fallowed field was divided into three replicates with two main plots (50 x 14 –m) seeded with an early and medium-early variety (Pioneer-87G57, NC+5C35) on 12 June 2003 for a final population of 8 plants $m^{-2}$. Main plots were subdivided (50x7 m) for uniformly planted, 17 cm between plants (SP-17), rows 0.75 m apart or clumps of 6 plants every 100 cm (C6-100) in rows 0.75 m apart. These plots were further subdivided lengthwise to test the effects of 0 or 1.2 Mg $ha^{-1}$ wheat straw on soil water. In 2004, the experiments were conducted on a bench-terraced watershed divided into two areas (120 m x 32 m) that were stubble-mulch tilled during fallow. Runoff from the upper two-thirds of the watershed collected on the level bench with some runoff from the upper one-third infiltrating into the soil of the middle-third. The resulting soil water contents varied across the watershed with the upper-third having the least water, the lower-third (level-benched area) having the most, and the middle-third having intermediate levels. A medium early hybrid was planted by 23 June 2005 in rows 0.75 m apart with uniform 25 cm interval between plants (SP-25), a three plant clump every 75 cm (C3-75), and a four plant clump every 100 cm (C4-100), Fig. 1. The final plant densities for the SP-25, C3-75, and C4-100 were 5.4 plants $m^{-2}$.

For grass and broadleaf weed control, atrazine (2-chloro, 4-ethyl amino-6-isopropylamino-1, 3,5 triazine) was applied at 2.4 kg a.i. $ha^{-1}$ as a pre-emergence herbicide using a field sprayer in 2003, but crop injury was observed. No seasonal weed control herbicide was used in 2004 to avoid crop injury. Fertilizer was not applied during either year because of negligible dryland crop response to P and K nutrients and because sufficient N is miner-

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alized during the previous 11 month fallow to meet dryland crop needs (Jones and Popham, 1997).

Gravimetric soil water content at seeding and at harvest was determined in 30-cm increments to a 1.8-m depth and converted to volumetric basis using previously measured bulk density. Plant tiller numbers were determined at 20 to 30 days after planting, DAP, and panicle number was recorded after flag leaf stage. Leaf area and aboveground biomass was measured periodically during the growing season. At physiological maturity, we hand harvested three 2-m length samples from the interior rows of each plot to determine biomass, and grain yield (adjusted to 130 g $kg^{-1}$ moisture). Treatment effects were compared using the General Linear Models ANOVA procedure (SAS, 1998). When main effects were significant, treatment means for dependent plant characteristics were separated using a protected LSD separation using $P = 0.05$.

**Results 2003**

Precipitation during June was > 50% above average (41 mm) that resulted in favorable early growing conditions, however precipitation was limited during the remainder of the growing season that led to severe water stress at anthesis and during grain filling. There were approximately 3 tillers $plant^{-1}$ for uniformly spaced sorghum; however, clumped sorghum averaged < 1 tiller $plant^{-1}$ (Table 1). No straw mulch or cultivar maturity effects on tillering were identified. Because of tillering, significant differences in aboveground biomass were measured 35 d after planting, i.e., uniformly spaced plants produced from 50 to 90% more biomass than the clumped plants. Similarly, the sorghum leaf area index, LAI, decreased significantly from 0.80 $m^2$ $m^{-2}$ for uniformly row planted sorghum to 0.45 $m^2$ $m^{-2}$ for clumped sorghum. Again, straw mulch and cultivar treatment effects resulted in no significant differences in biomass and LAI. Soil water and nutrient consumption by the smaller clump planted sorghum was probably less than for the larger uniformly planted sorghum. More importantly, smaller plants with decreased LAI will require less water for transpiration as the growing season continues.

As sorghum matures, panicles production increases in relation to soil water and nutrients availability during the later growing season. Clump planted sorghum produced in ~ 40% more panicles per unit area than uniformly planted sorghum resulting in more potential grain yield, but straw and cultivar effects were negligible. Grain yield averaged across straw and cultivar treatments increased ~ 75 % from 680 kg $ha^{-1}$ for uniformly planted sorghum to 1195 kg $ha^{-1}$, while aboveground biomass decreased an average 16% from 4100 kg $ha^{-1}$ with uniform rows to 3440 kg $ha^{-1}$ with clumps. What this means is that the available soil water and nutrient resources at planting were more efficiently converted to grain instead of stems and leaves by sorghum planted in clumps regardless of cultivar. And, any difference in evaporation for row and clump planting geometries was unaffected by the straw mulch.

**Results 2004**

Precipitation during 2004 was 42 mm above the long-term average June through September amount of 306 mm and resulted in grain yields 2 to 3 times higher than measured in 2003. Nevertheless, the number of tillers $plant^{-1}$ observed 28 d after planting for uniformly spaced sorghum was usually double that for the clumped sorghum at < 1 tiller $plant^{-1}$ planted on stubblemulch tillage plots (Table 2). Tiller reduction with clumps appeared to be more effective going up the terraces from the level bench to the more droughty upper position. Technically, we may not statistically compare terrace position effects on tillering, but treatment effects across the uniform Pullman soil are usually reliable. Differences in tillering contributed to significant differences in aboveground biomass observed 42 d after planting within the terrace position and residue management experiments. That is, uniformly spaced plants produced from 50 to 90% more biomass than the clumped plants, which confirms the 2003 test results. Although greater than in 2003, sorghum LAI for clumped sorghum was significantly lower compared with uniformly row planted sorghum in stubblemulch tillage plots (Table 2). Again, the smaller clump planted sorghum with decreased LAI will require less water for transpiration and can defer water and nutrient consumption for later grain fill.

Efficient water and nutrient use by maturing sorghum is sometimes indicated by panicles $m^{-2}$. During 2004, with its favorable rain, panicle numbers increased as the number of tillers increased (Table 2); however, a high percentage of fertile tillers indicates efficient use of nutrient and water resources. Fertile tillers for uniformly planted no-tillage sorghum averaged 43% compared with 68 and 78% for the C3-75 and C4-100 plots (respectively). Likewise, under stubblemulch tillage, fertile tillers were 41% for uniform SP-25 sorghum compared with 88% for both C3-75 and C4-100 sorghum.

Grain yield and biomass production during the 2004 experiment increased as available water increased going down the terrace (Table 2). On the level-terrace benches, where available water met crop needs, grain yield ranged from 4700 to 4900 kg $ha^{-1}$ and did not vary with planting geometry. Biomass, however, was greater for uniformly planted sorghum and this decreased the harvest index. On the middle and upper terrace positions grain yield and aboveground biomass decreased because of less infiltrating runon water available to the crop. Sorghum grain yields were consistently lower for uniformly planted rows, SP-25, compared with C3-75 and C4-100, but biomass did not vary significantly with planting geometry. The corresponding harvest index decreased with decreasing grain yields on middle and upper terrace positions and with uniformly planted, SP-25, sorghum. These data show that equally available water and nutrient resources at planting were more efficiently converted to grain instead of stems and leaves by clump planted sorghum.

**Conclusions**

Because dryland grain sorghum on the southern High Plains is usually planted on soil with abundant plant available water during the wettest part of the year, excessive vegetative growth and tillering produces a large plant that consumes water and nutrients needed for grain. Planting sorghum in clumps decreases tillering and biomass production, possibly as a result of increased competition among plants or differences in plant conformation that decreases transpiration and tillering. This experiment, led by Bob Stewart, revealed that clump planting geometries increased dryland grain sorghum yield by deferring soil water use until later in the growing season when precipitation is limited. As for me, finding that uniform planting geometries did not maximize crop yields during two studies with very different years challenged my basic agronomic understanding that uniform planting geometries were ideal.

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Table 1. Mean values of select grain sorghum characteristics as affected by hybrid and planting geometries in 75-cm rows for the 2003 experiments at Bushland, TX.

| TREATMENT† | Tillers plant$^{-1}$ 20 DAP§ | Biomass 35 DAP (kg ha$^{-1}$) | Leaf area index 35 DAP | Panicles m$^{-2}$ | Grain (kg ha$^{-1}$) | Harvest Index ¶ | Above-ground biomass (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| **Pioneer 87G57** | | | | | | | |
| SP-17 STRAW | 3.2a‡ | 963a | 0.77a | 6.0a | 795b | 0.15b | 4604a |
| SP-17 NO-STRAW | 3.1a | 996a | 0.82a | 4.3b | 544b | 0.13b | 3708b |
| C6-100 STRAW | 0.6b | 503b | 0.44b | 6.9a | 1370a | 0.33a | 3637b |
| C6-100 NO-STRAW | 0.6b | 570b | 0.45b | 6.9a | 1135a | 0.28a | 3523b |
| **NC+5C35** | | | | | | | |
| SP-17 STRAW | 3.2a | 830a | 0.72a | 4.9b | 772b | 0.17b | 4010a |
| SP-17 NO-STRAW | 3.0a | 897a | 0.76a | 4.3b | 607b | 0.13b | 4064a |
| C6-100 STRAW | 0.7b | 542b | 0.44b | 6.7a | 1269a | 0.33a | 3254b |
| C6-100 NO-STRAW | 0.6b | 580b | 0.50a | 6.2a | 1007a | 0.27a | 3352b |

† Treatments consisted of two hybrids (Pioneer 87G57 and NC+5C35) and two planting geometries (SP-17, plants every 17 cm and C6-100, clumps of 6 plants every 100 cm) in rows 75 cm apart.

§Days after planting (DAP).

¶ Harvest index based on dry weight of grain divided by dry weight of aboveground biomass.

‡Means within columns followed by the same letter are not significantly ($P < 0.05$ level) different according to a protected LSD mean separation.

Table 2. Mean values select grain sorghum characteristics as affected by planting geometries in experiments located on the upper (Upper), middle (Middle) and bench (Bench) terrace positions of a stubble-mulched field at Bushland, TX in 2004.†

| PLANTING GEOMETRY‡ | Tillers plant$^{-1}$ 28 DAP§ | Biomass 42 DAP (kg ha$^{-1}$) | Leaf area index 42 DAP | Panicles m$^{-2}$ | Grain (kg ha$^{-1}$) | Harvest index ¶ | Aboveground biomass (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| **Upper** | | | | | | | |
| SP-25 | 1.8a# | 2880a | 1.31a | 8.1a | 2385c | 0.28c | 7472a |
| C3-75 | 0.7b | 1900b | 1.01b | 7.7a | 2976b | 0.36b | 7251a |
| C4-100 | 0.3b | 1617c | 0.87c | 6.2b | 3563a | 0.41a | 7623a |
| **Middle** | | | | | | | |
| SP-25 | 2.0a | 2758a | 1.41a | 10.6a | 3180b | 0.34b | 8204a |
| C3-75 | 1.1b | 1919b | 1.12b | 9.5a | 4013a | 0.41a | 8586a |
| C4-100 | 0.5c | 1732c | 0.90c | 8.1b | 3952a | 0.44a | 7879a |
| **Bench** | | | | | | | |
| SP-25 | 2.3a | 3015a | 1.44a | 12.0a | 4743a | 0.41b | 10 148a |
| C3-75 | 1.2b | 2150b | 1.18b | 9.9b | 4902a | 0.46a | 9 348b |
| C4-100 | 0.8c | 1806c | 0.93c | 8.8b | 4810a | 0.46a | 9 172b |

†Separate but identical experiments were conducted on three positions that had different amounts of stored soil water at time of seeding and different amounts of runoff or run-on during the cropping season.

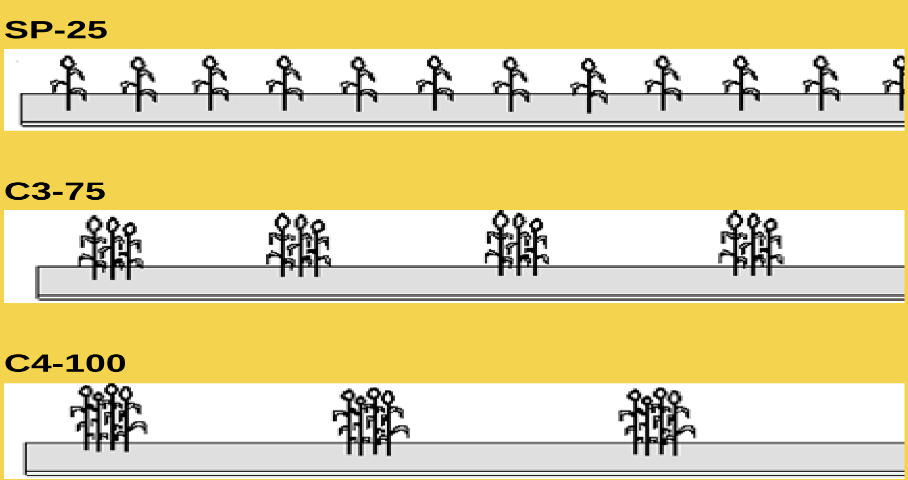
‡Planting geometries were SP-25 (plants every 25 cm), C3-75 (clumps of 3 plants every 75 cm), and C4-100 (clumps of 4 plants every 100 cm) in 75 cm rows.

§Days after planting (DAP).

¶ Harvest index based on dry weight of grain divided by dry weight of aboveground biomass.

# Means within columns and the same terrace position followed by the same letter are not significantly ($P < 0.05$ level) different according to a protected LSD mean separation.

**Figure 1.** Schematic of planting geometries used in 2004 including single plants every 25 cm (SP-25), three plants per clump every 75 cm (C3-75), and four plants per clump every 100 cm (C4-100) with 75 cm between rows and a constant population of 5.4 plants m$^{-2}$.

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**References**

*Bandaru, V., B.A. Stewart, R.L. Baumhardt, S. Ambati, C.A. Robinson, and Alan Schlegel. (In Press) Growing Dryland Grain Sorghum in Clumps to Reduce Vegetative Growth and Increase Yield. Agron. J.*

*Baumhardt, R.L., J.A. Tolk, and S.R. Winter. 2005. Seeding practices, and cultivar maturity effects on simulated grain sorghum yield. Agron. J. 97:935-942.*

*Craufurd, P.Q., D.J. Flower, and J.M. Peacock. 1993. Effect of heat and drought stress on sorghum (Sorghum bicolor). I. Panicle development and leaf appearance. Exp. Agric. 29:61-76.*

*Jones, O.R. and T.W. Popham, 1997. Cropping and tillage systems for dryland grain production in the Southern High Plains. Agron. J. 89:222-232.*

*Larson, E.J., and R.L. Vanderlip. 1994. Grain sorghum yield response to nonuniform stand reductions. Agron. J. 86:475-477.*

*SAS Institute. 1998. SAS/STAT user guide. Release 6.3. SAS Ins., Cary, NC.*

*Steiner, J.L. 1986. Dryland grain sorghum water use, light interception, and growth responses to planting geometry. Agron. J. 78:720-726.*

*Unger, P.W. 1978. Straw-mulch rate effect on soil water storage and sorghum yield. Soil Sci. Soc. Am. J. 42:485-491.*

*Unger, P.W. and R.L. Baumhardt. 1999. Factors related to dryland grain sorghum yield increases, 1939 through 1997. Agron. J. 91:870-875.*

## Technology Transfer News

Paul Colaizzi and Don McRoberts assisted Dr. Sangu Angadi, New Mexico State University, Clovis, NM with a design for an SDI research and demonstration field in February 2006.

During the week of February 6, Steve Evett and Brice Ruthardt provided training on TDR moisture probe construction, operation of the TACQ TDR data acquisition program, and set up and use of field TDR systems to Jason Ward and Karl Mannschreck from the USDA-ARS National Soil Dynamics Laboratory.

Soil Scientist Steve Evett traveled to Jordan on April 13-20, 2006 to work with the Middle Eastern Regional Irrigation Management Information System (MERIMIS, see at [http:// www.merimis.org/index.html](http://www.merimis.org/index.html)) project. The MERIMIS project is funded by DOS through USDA-ARS-OIRP. Dr. Evett worked with Dr. Naem T.I. Mazahrih of the Jordanian National Center for Agricultural Research and Technology Transfer (NCARTT) on the design of a weighing lysimeter for crop water use measurements in the Jordan Valley at the Dayr Alla Agricultural Research Station.

Paul Colaizzi was interviewed by KGNC Ag Radio on May 5, 2006 on the latest findings of subsurface drip irrigation (SDI) at Bushland.

Steve Evett and Brice Ruthardt provided training to Andy Cranmer of the Texas Agricultural Experiment Station on running three computer programs for soil moisture determination using TDR equipment on May 10, 2006.

## Meetings & Presentations

Soil Scientists Steve Evett and Robert Schwartz attended the Western Soil Physics Committee W1188 meeting in Las Vegas, NV, January 3-4, 2006, where they presented a report on research progress at Bushland.

Soil Scientist Steve Evett visited the USDA-ARS laboratory at Parlier, CA, January 30-Februrary 1, 2006 where he collaborated with Agricultural Engineer Jim Ayars on a TDR system for soil water measurement in a peach orchard experiment, and discussions on the MERIMIS project.

Soil Scientist Steve Evett participated as a member of the external science panel in a review of the NSF funded project "Scaling Environmental Processes in Heterogeneous Arid Soils" (SEPHAS) at Las Vegas, NV, February 2, 2006.

Paul Colaizzi and Terry Howell met with Texas A&M University Department of Biological and Agricultural Engineering faculty in Amarillo, TX, February 14-15, 2006 to discuss strategic planning to coordinate statewide irrigation research and extension programs.

Paul Colaizzi and Terry Howell attended the Central Plains Irrigation Association Conference and Exposition in Colby, KS February 21-22, 2006 and presented papers "Crop production comparison under various irrigation systems" and "Water Losses Associated with Center Pivot Nozzle Packages."

Soil Scientist Steve Evett presented the keynote talk "Water Resources for Rice Production in the United States" to the 31st Rice Technical Working Group Meeting in The Woodlands, TX, February 27, 2006.

All Unit Scientists attended the Ogallala Initiative Workshop in Amarillo, TX, March 7-9, 2006 where they presented project-related research results to colleagues and customers.

Paul Colaizzi and Prasanna Gowda visited scientists at the USDA-ARS Hydrology and Remote Sensing Laboratory in Beltsville, MD, March 12-15, 2006 for training in satellite atmospheric correction and to discuss collaboration on ET remote sensing research as part of the next five-year cycle of NP 201.

Soil Scientist Steve Evett presented "Increasing Water Use Efficiency through International Cooperation" in Beltsville, MD, April 4, 2006, as part of the ARS International Research Seminar Series. He also discussed international research programs in the Middle East and Uzbekistan with the ARS Office of International Research Programs, and meet with Ghassem Asrar, Deputy Administrator, USDA-ARS Natural Resources & Sustainable Agricultural Systems.

T.A. Howell, Research Leader, presented an invited keynote paper on "Challenges in Increasing Water Use Efficiency in Irrigated Agriculture" to the International Symposium on Water and Land Management for Sustainable Irrigated Agriculture, Adana-TURKEY, 4 – 8 April, 2006, Cukurova Univ.

Paul Colaizzi and Prasanna Gowda hosted Bridget Scanlon, Department of Economic Geology, University of Texas, Austin April 5, 2006 to discuss opportunities for collaboration in aquifer recharge and ET remote sensing.

Soil Scientist Steve Evett attended the Middle East Water Management Meeting jointly held by MERIMIS and the Middle Eastern Meteorological System (MEMS) project on April 19, 2006 at the Cooperative Monitoring Center (CMC) at the Royal Scientific Society in Amman where he delivered the presentation "Water Resource Use Efficiency in the Middle East and the United States".

# Historic Tree Row Restoration Update

By J.A. Tolk

In April, 2006, phase II of the historic tree row restoration project was completed, with the planting of 90 Austrian pine and 50 bur oaks in N-S rows just west of the main entrance road. In the photo above, you can see the lines of trees remaining from the first planting in 1939 plus the new trees with the headquarters in the distance. In the three bottom photos, plastic mesh (l) protects the pine trees and tubes (r) protect the oaks (c) from rodent damage. We are thrilled with the growth of the lace bark elms in just one year (about 4 ft tall) as you can see the comparison of "before" and "after" on the right. We hope to (and need to because it's so dry) get the drip system installed soon.

**Soil and Water Management Research Unit**

**http://www.cprl.ars.usda.gov**

**RESEARCH STAFF**

Dr. Terry A. Howell, P.E.
Research Leader (Agric. Engr.)
(806) 356-5746
tahowell@cprl.ars.usda.gov

Dr. R. Nolan Clark
Laboratory Director (Agric. Engr.)
(806) 356-5734
rnclark@cprl.ars.usda.gov

Dr. R. Louis Baumhardt
Soil Scientist
(806) 356-5766
rlbaumhardt@cprl.ars.usda.gov

Dr. Paul D. Colaizzi
Agricultural Engineer
(806) 356-5763
pcolaizzi@cprl.ars.usda.gov

Karen S. Copeland
Soil Scientist
(806) 356-5735
kcopeland@cprl.ars.usda.gov

Dr. Steven R. Evett
Soil Scientist
(806) 356-5775
srevett@cprl.ars.usda.gov

Dr. Prasanna Gowda
Agricultural Engineer
(806) 356-5730
pgowda@cprl.ars.usda.gov

Dr. Robert C. Schwartz
Soil Scientist
(806) 356-5762
rschwart@cprl.ars.usda.gov

Dr. Judy A. Tolk
Plant Physiologist
(806) 356-5736
jtolk@cprl.ars.usda.gov

Donald A. Dusek
Collaborator (Agronomist)
(806) 356-5747
ddusek@cprl.ars.usda.gov

Dr. Paul W. Unger
Collaborator (Soil Scientist)
(806) 356-5749
pwunger@tcac.net

## Publication Contact . . .

The *Wetting Front* publication is designed to foster technology transfer from our research to industry and to agricultural producers in the Southern High Plains and to improve communications with our stakeholders and partners.

For actions or corrections to our mailing list, contact Mrs. Carole Perryman by one of the following:

fax: (806) 356-5750
email: cperryman@cprl.ars.usda.gov
phone: (806) 356-5749
mail: USDA-ARS, P.O. Drawer 10, Bushland, TX 79012

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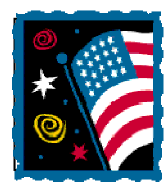

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